DOCUMENT RESUME

ED 324 191 SE 051 314

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TITLE Development of a Paper-and-Pencil Instrument To Elicit Student Concepts Concerning the Earth as a Planet.
PUB DATE 90
NOTE 43p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (63rd, Atlanta, GA, April 8-11, 1990). Four diagrams of the earth will not reproduce well due to extremely small type.
PUB TYPE Reports - Research/Technical (143) -- Tests/Evaluation Instruments (160)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Affective Measures; *Earth Science; Elementary Secondary Education; Junior High Schools; *Middle Schools; Science Education; *Science Tests; *Secondary School Science; *Student Attitudes; Test Construction; Test Reliability

ABSTRACT

This document presents a two-part study. In the first part, open-ended questions based on interview studies were administered via paper-and-pencil tasks to 76 sixth and eighth grade students. In the second part, the earth and sun relationship questions were extracted, modified, and given to 178 seventh grade students. In part one, the performance of the students on the earth orientation tasks was compared to the performance of students in previous cross-age studies and no significant difference was detected between the two groups. In part two, an analysis of pretest results showed differences between the ability-grouped classes, but not for non-ability-grouped classes. Post-test analysis showed significant increases in the overall scores of the instructed classes. An analysis of covariance showed no differences between the gains of the students in different schools or the classes of different abilities. It was concluded that the instrument developed was a reliable means of eliciting and assessing student concepts in earth science. Statistics describing individual items and the overall test are included. Copies of versions of the test and instructions for coding the answers are included. (CW)

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Development of a Paper-and-Pencil Instrument to Elicit Student Concepts Concerning the Earth as a Planet

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presented at
the Annual Meeting of
The National Association for Research in Science Teaching

April 8-11, 1990

SE051314

List of Tables and Figures

	page
Table 1. Student Replies on the Earth-Orientation Tasks	4
Table 2. Number by Grade of Earth-Orientation Tasks Performed Correctly.	5
Table 3. Combined Data from the Earth-Orientation Interview Studies	6
Table 4. Replies on the Earth, Sun and Moon Questions	7-8
Figure 1. Proportion of Geocentric Children from the Interview Studies	9
Figure 2. Comparison of Data from the Paper-and-Pencil Test to the Regression of the Data from the Interviews	10
Table 5. Distribution of Answers on the Earth, Sun, Moon Test	12
Table 6. Pretest and Posttest Averages and Deviations by School and Class	13
Table 7. Student Replies on the Earth and Sun Test, Version 1	14-15
Table 8. Item analysis showing proportion correct for matched students.	17
Bibliography	18

Appendix

Samples of the Earth-orientation tasks versions (free choice, North Carolina and Australia.

The Earth, Sun and Moon questions.

The Earth and Sun Instrument, version 1.

The Earth and Sun Instrument, current version.

Coding sheet for Earth and Sun Test.

This research was supported by a grant from the Organized Research Fund, School of Education and Psychology, North Carolina State University.

Development of a Paper-and-Pencil Instrument to Elicit Student Concepts Concerning the Earth as a Planet

Abstract

This study was concerned with developing a paper-and-pencil instrument that could be used by classroom teachers to elicit and assess student concepts concerning the earth as a planet.

Previous studies in this area have used interviews to elicit children's ideas, but this technique is considered impractical for classroom teachers to use. Studies in other areas have developed two-tiered, multiple-choice tests, but this method has been shown to produce significantly different results from interviews. Therefore, open-ended questions were selected for the instrument since they have been shown to produce results comparable to those from interviews.

The study was divided into two parts. In the first part, the open-ended questions based on the interview studies were administered via paper-and-pencil tasks to 76 middle school students in grades 6 and 8. In the second part, the earth and sun relationship questions were extracted, modified, added to and given to 178 seventh graders as the first edition of the instrument.

In part one, the performance of the students on the earth-orientation tasks were compared to a regression line of the proportion of correct, earth-centered children combined from previous cross-age studies. The proportions of those sixth and eighth graders determined to be predominately earth-centered from the paper-and-pencil tasks were not significantly different from the proportions projected by the regression (alpha = .05) but did tend to be below the line.

On the earth, sun and moon relationship questions, the proportion of correct answers for the sixth graders on this instrument (76%) were similar to those from the interview study (73%). Otherwise, there were no significant differences between the replies of the sixth and eighth graders using a Chi-square.

In part two of the study, the first edition of the instrument was developed containing the earth and sun relationship questions and given as a pre- and post test to seventh grade classes in three different schools. An ANOVA of the pretest results, using only number of correct replies, showed significant differences between the ability-grouped classes at one school, but the mean scores were not signficantly different for classes at the two other schools

that did not have ability-grouped classes. (However, there were significant differences between all three schools). An internal reliability of .73 was obtained from the pretest.

For the posttest, one school served as a retest control group and their posttest scores correlated with an r = .83 to their pretest scores. From the school with no ability classes, the highest and the lowest of the four classes available were selected as comparisons for the ability-grouped classes at the other school. All four instructed classes showed significant increases in their overall scores with students who scored higher on the pretest showing lower gains on the average than students who scored lower on the pretest. However, an Analysis of Covariance showed no significant differences between the gains of students in the two schools (p=.22) and between classes of different abilities (p=.38).

In conclusion, it was determined that the developed instrument was a reliable means of eliciting and assessing student concepts in this area. After some small revisions, the second edition of the instrument will be retested. In addition, teachers will be asked to score the instruments so an inter-rater reliability measure can be determined.

PURPOSE OF THE STUDY

The purpose of this study was to develop an instrument that would elicit students' concepts of the Earth as a planet which could also be used as an assessment instrument by the classroom teacher. This develoment consisted of two parts. In the first part, questions from earlier interview studies were given to a sample of middle school students via a paper-and-pencil test to see if the distributions of answers elicited were comparable to those elicted through the interview method. In the second part of this study, a set of questions were extracted and written from the first study to match specific objectives of the state course of study and administered to a sample of seventh graders to see if it was a reliable measure of student knowledge.

Related literature

Previous assessments of these concepts used structured interviews: Nussbaum & Novak (1976), Nussbaum (1979), Sneider & Pulos (1983), and Mali & Howe (1980) for earth orientation; Klein (1982) for concepts of the earth and sun; and Jones, Lynch & Reesink (1987) for conceptions of the earth, sun and moon.

Other areas of the study of misconceptions in science have used, in addition to the interview approach, two-tiered multiple choice tests in which the student selects an answer and a reason for the answer from a separate list. In order to be considered as having the proper concept, both answers selected must be the correct ones (e.g., Group Assessment of Logical Thinking, see Tobin & Capie, 1981). In a format for developing these two-tiered diagnostic tests to evaluate students' misconceptions in science, Treagust (1988) suggested "obtaining responses from open-ended pencil and paper questions" (p. 162) along with interviews in order to ascertain the common misconceptions held by the children on the topics to be included as the incorrect responses of the multiple-choice test. However, Bar (1987) did a comparison of interviews, multiple-choice and open-ended questions to elicit concepts. The results showed the open-ended questions elicited similar responses to the interviews whereas the multiple-choice questions produced significantly different results. Also, in a comparison of first year university students in chemistry, Seddon & Pedrosa (1988) found no significant differences between

explanations given by spoken and written methods of questioning.

Therefore, the two-tiered, multiple-choice test was rejected as being inadequate at eliciting the variety of unique responses known to be held by students and the open-ended, paper-and-pencil test was explored as a possible concept elicitation tool which could also be used by teachers to do a general assessment of the views held by their students prior to teaching.

SIGNIFICANCE

The significance of concept elicitation can be found in the suggested approach to teaching science recommended by the conceptual development and constructivist approach. Nussbaum and Novick (1982) recommended science instruction be preceded by the following (p.188):

> 1.a. Creation of an "exposing event" which requires students to invoke their preconceptions.
>
> b. Encouraging the students to describe their preconceptions, both verbally and pictorially.
>
> c. Assisting the students to state their ideas clearly and concisely, thereby making them aware of their own preconceptions.
>
> d. Encouraging confrontation in which students debate pro's and con's of their different preconceptions.

In a similar manner, Driver and Oldham (1986) recommended for a constructivist teaching sequence (p. 117-119):

> **Phase II**. An <u>elicitation phase</u> when students make their ideas explicit and bring them to their own conscious awareness.
>
> **Phase III**. <u>Restructuring of ideas</u>:
>
> A. Clarification and exchange - the students compare their views with the scientific alternative and conflicting views of other students.

Therefore, an elicitation tool which could also serve as an assessment for teacher awareness would be very important in accomplishing the "drawing out" of preconceptions on a topic.

DESIGN

Part 1.

In the first part of this study, a set of tasks and questions, based on the earlier interview studies were developed (see Appendix A). These were then divided into four sets. Three sets dealt with the earth-orientation tasks (Nussbaum & Novak, 1976)—one with a free choice of position upon a picture of a globe to draw their responses, one with North Carolina outlined on the picture of the globe where they were asked to draw their responses, and the third with Australia outlined. The fourth test consisted of the questions pertaining to the earth, sun and moon relationships.

These four tests were interleaved and sets given to each of four cooperating teachers from four different area middle schools to administer to at least one of their classes. This assured a random selection of tests would be given to the pupils (n = 76).

Part 2.

For the instrument that would be tested, the earth and sun relationships were selected. These concepts are taught in the seventh grade in the public schools of this area, whereas, there is no direct instruction concerning earth-orientation in the middle school. The pertinent questions were extracted from the original instrument and several more were written using the same open-ended form in order to cover all of the state competencies suggested for that unit. This instrument was given to seventh grade students in three middle schools—one rural (n = 50), one magnet inner-city (n = 80) and one private (n = 48). The private school students did not receive any instruction on these topics, but completed the instrument three weeks later as a retest reliability measure (n = 45).

PROCEDURES

Study 1.

For the five earth-orientation tasks, the student drawings were coded by the researcher for correct orientation and alternative orientations (see Table 1). There appeared to be some consistent differnces among the three versions. On the free-choice of position, it was difficult to ascertain if a drawing on the top of the globe

represented a correct or egocentric orientation.

Table 1.

Student Replies on the Earth-Orientation Tasks

		Earth	N.C.	Austr.	**Total**	%
Task 1:	Orientation of a standing person.					
	a. Correct (Earth-centered)	7	7	3	17	22%
	b. Egocentric up and down.	14	9	18	41	54%
	c. Parallel to edge.	0	6	3	9	12%
	d. Other.	4	3	0	7	9%
Task 2:	Direction of fall of a dropped rock.					
	a. Toward Earth's center.	5	8	2	15	20%
	b. Toward bottom of paper.	15	9	14	38	50%
	c. Sideways.	0	4	3	7	9%
	d. Other.	7	4	5	16	21%
Task 3:	Rock dropped down a deep hole.					
	a. Toward Earth's center.	3	6	4	13	17%
	b. Toward bottom of paper.	9	7	6	22	29%
	c. Sideways.	0	0	2	2	3%
	d. Other.	13	12	12	37	49%
Task 4:	Direction of a rock thrown upward.					
	a. away from Earth's center.	9	3	5	17	22%
	b. Toward top of paper.	11	8	11	30	39%
	c. Sideways.	0	0	2	2	3%
	d. Other.	7	14	6	27	36%
Task 5:	Rock dropped down a shaft completely through the Earth.					
	a. Through Earth's center.	12	8	3	23	30%
	b. Straight down paper.	2	10	2	14	18%
	c. Sideways (not thru ctr.)	0	0	3	3	4%
	d. Other.	13	7	11	31	41%

Students were considered to have the correct, earth-centered orientation if they mostly used it on the tasks with no more than one incorrect orientation (egocentric up and down). Students were considered transitional if they used the correct and egocentric orientations about half and half. Students were considered egocentric if they used mostly that orientation with no more than one answer that could be considered correct. (See Table 2.)

Table 2.
Number by Grade of Earth-Orientation Tasks Performed Correctly.

		Egocentric		Transitional		Geocentric	
Grade	# correct	0	1	2	3	4	5
6th		28	11	4	4	1	2
			(56%)		(30%)	(14%)	
7th		2		2			
8th		5	1	6	3	2	1
			(28%)		(39%)	(33%)	

In order to compare the answers obtained by this paper-and-pencil assessment, the data from the other studies were redivided so that the students in categories 1 and 2 were classified as egocentric and those in categories 4-5 as earth-centered (category 3 is considered transitional, see Nussbaum, 1979) (See Table 3, also see Graph 1.)

The proportion of earth-centered children at each age from all of the previous studies were combined in a regression analysis (see Graph 2). The proportion of children determined to be earth-centered from this study at the two ages assessed were compared to the regression line means using t-tests.

Table 3.
Combined Data from the Earth-Orientation Interview Studies.

		Egocentric			Geocentric	
Grade	Age	Ntn.1	Ntn.2	Ntn.3	Ntn.4	Ntn.5	n =
2nd	8	113	44	9	17	4	188
			83%			11%	
3rd	9	9	9	12	0	0	30
			60%			0%	
4th	10	89	20	38	15	3	165
			66%			13%	
5th	11	5	12	24	9	20	70
			24%			42%	
6th	12	44	10	33	37	16	140
			38%			37%	
7th	13	2	7	10	14	41	72
			13%			78%	
8th	14	5	9	16	11	34	75
			19%			60%	

For the earth, sun, moon relationship questions, the replies (n = 24) were also coded for correct and incorrect answers, blank and indecipherable answers (see Table 4 for a summary of replies). Differences in the performance of the 6th and 8th graders were measured using a Chi-square.

Study 2.

A 14-item instrument was developed from the questions used in the earth and sun relationship interviews and some additional questions were designed in order to match all of the competencies suggested for this unit in the seventh grade. Three seventh-grade teachers; one from a rural school, one from a private school and one from an inner-city, magnet school; agreed to participate in the field-testing of this new instrument.

Table 4.

Replies on the Earth, Sun and Moon Questions.

Concept	Number	Percent
1. Shape of the Earth.		
a. Spherical	13	54%
b. Round	7	29%
c. Circle	4	17%
2. Moon's relationship with the Earth.		
a. Orbits it in space.	9	37%
b. It is in the sky/atmosphere.	4	17%
c. Other.	11	46%
3. Why can't we see the Moon sometimes?		
a. On the other side of the Earth.	9	37%
b. Sunlight drowns it out.	5	21%
c. Other.	10	42%
4. Earth's relationship with the Sun.		
a. Orbits it far away in space.	6	25%
b. The Sun is in the sky.	2	8%
c. Other.	16	67%
5. Why can't we see the Sun at night?		
a. We are facing away from it.	11	46%
b. The Sun rotates away from the Earth.	2	8%
c. Earth revolves around the Sun each day.	2	8%
d. Other.	9	38%
6. Relative sizes of the Earth, Sun and Moon:		
a. The Sun is the largest.	20	83%
b. The Moon is the smallest.	20	83%
c. The Earth is the largest.	3	13%
d. The Earth is the smallest.	2	8%
7. Relative distances between the Earth, Sun and Moon:		
a. The Moon is closer.	19	79%
b. The Sun is closer.	5	21%
Differences in lengths of daylight in days:		
8. Daylight is longer in the Summer.	15	63%
9. Daylight is shorter in the Winter.	17	71%

Table 4, Replies on the Earth, Sun and Moon questions (continued)

Concept	Nr.	%
10. Reason for longer daylight.		
a. Tilted toward the sun.	1	4%
b. Closer to the sun.	4	17%
c. We set clocks forward.	3	13%
d. Other and blank.	16	67%
11. Reason for shorter daylight.		
a. Tilted away from the Sun	0	
b. Further from the Sun.	4	17%
c. We set clocks back.	3	13%
d. Other and blank.	17	71%
12. Cause of the Moon's phases.		
a. Relative positions of earth	1	4%
and sun.	1	4%
b. Rotation of the Earth.	3	13%
c. Different angles of the Sun.	3	13%
d. Clouds cover part of it.	3	13%
e. Other and blank.	13	54%
13. What are the phases? (Drawings)		
a. Drew Full Moon	23	96%
b. Drew First Quarter	10	42%
c. Drew Last Quarter	9	38%
d. Drew Waxing Crescent	9	38%
e. Drew Waning Crescent	9	38%
f. Drew Waxing Gibbous	4	17%
g. Drew New Moon (colored in)	2	8%
h. Drew Waxing Gibbous	1	4%

The rural teacher had two ability-grouped classes. The private school had two classes where the students had been randomly assigned. The inner-city school teacher had four classes available which were not completely randomly assigned due to the magnet program scheduling. As a result, one class had a higher proportion of gifted children and another class had a higher proportion of remedial

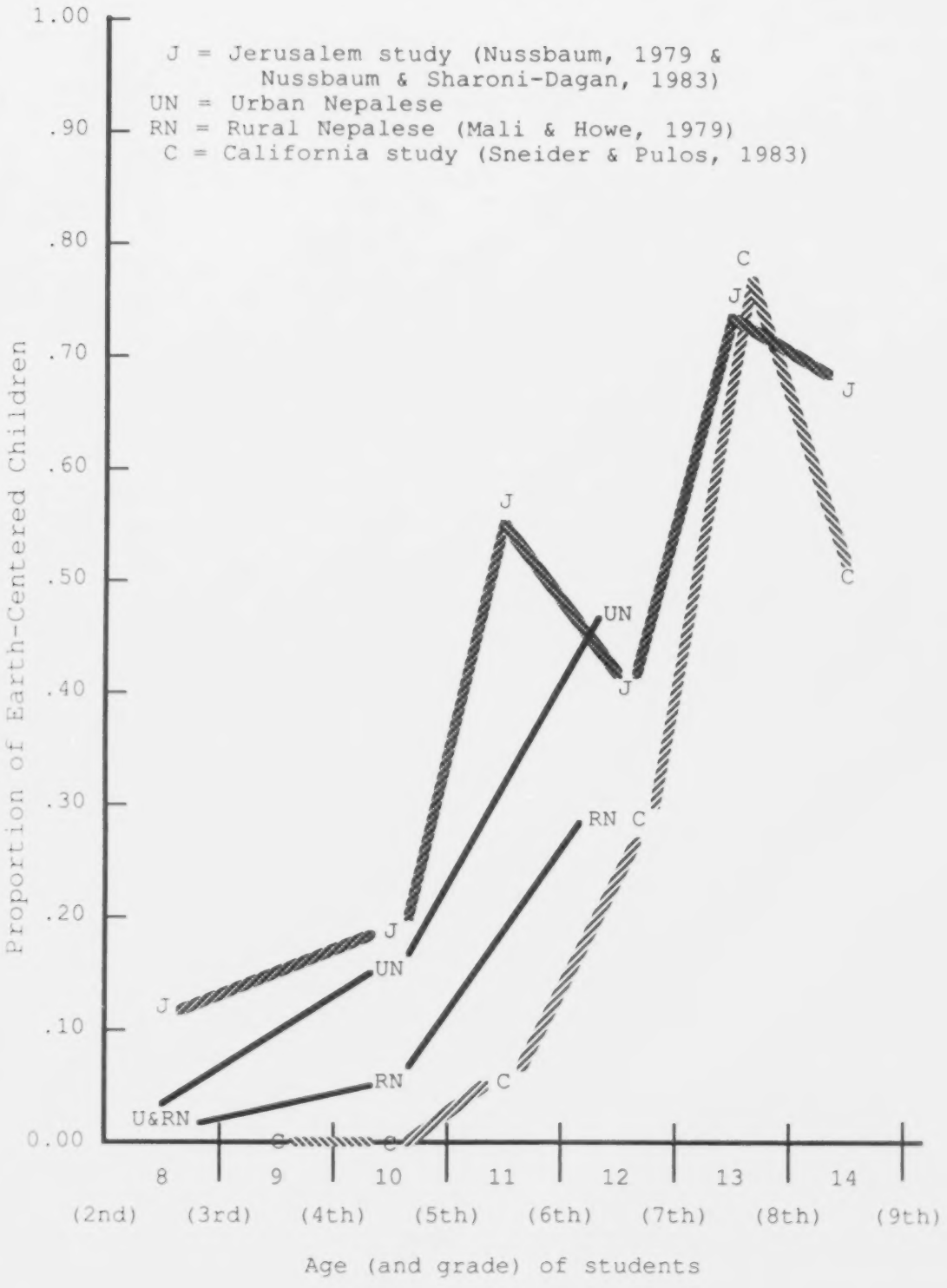

Figure 1. Proportion of Geocentric children from the interview studies.

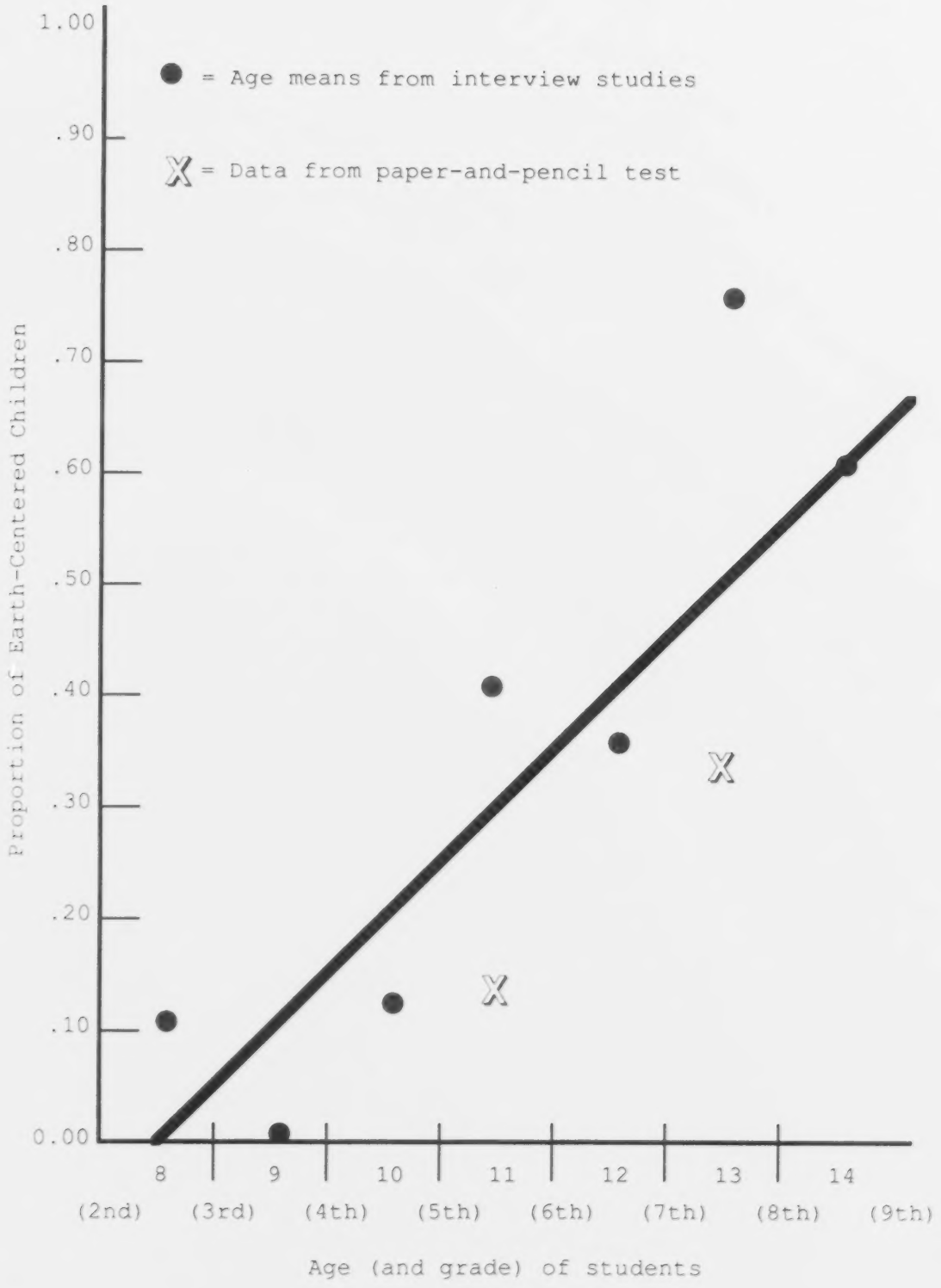

Figure 2. Comparison of data from the paper-and-pencil test to the regression of the data from the interviews.

students. It was decided to compare the results on the posttest by the high and the low classes from the inner-city school with those from the rural school after instruction. The private school classes served as a test-retest control group. Instruction at the other two schools differed in the following ways. At the rural school, instruction was didactic followed by review using worksheets in cooperative learning groups. At the inner-city school, students were taught using activities based on the learning cycle which they conducted as partners. Students were given the instrument as a pretest. Following instruction (except for the control group), the students answered the questions on the instrument again as a posttest.

The total number of correct answers was used in the analysis of student performance. Since the classes at the rural school were supposed to be of different ability levels, t-tests (alpha =.05) were used to compare the means of these classes on the pretest. All four classes at the inner-city school took the pretest and their average scores were compared with an Analysis of Variance. In addition, the scores of the two classes selected to represent a high and low ability class were compared using t-tests. Also, an overall Analysis of Variance was used to compare the pretest scores of all four selected classes from the two schools.

Finally, an item analysis was conducted on the combined pretests to determine internal reliability using the Kuder-Richardson Reliability Coefficient. An item analysis was also conducted by class to determine performance on individual questions as a result of the different instructional methods. The pre- and posttests from the private school were correlated in order to determine retest reliability using Pearson's r.

FINDINGS AND RESULTS

Part 1.

Earth orientation. In looking at the proportions of earth-centered children from the cross-age studies it was noticed that this proportion generally increases in the form of a growth curve (see figure 1). There are some individual peaks due to instruction but the students appear to regress to their preconceived

ideas by the following year. The regression produced a line with a correlation coefficient of .74 and r^2 of .55. The data from the present study were very close to the regression line ($t_{6th\ grade}$ = .94 and t_{8th} = .71, $t_{.05}$ with 6 d.f. = 2.447). Therefore, it appears that the paper-and-pencil form of these tasks was adequate for determining earth orientation. However, inspection shows that both "X's" fall below the line which suggests the paper-and-pencil instrument underestimats earth orientation compared to interviews.

Earth, sun, moon. The questions on the earth, sun, moon relationships elicited a wide variety of answers as expected from students personal replies unmediated by instruction (see Table 4). However, a t-test of correct answers showed no significant differences between the performance of the sixth and eighth graders (M_{6th} = 7.13 ± 3.4 and M_{8th} = 8.25 ± 3.2, $t_{.05}$ = .78). A chi-square between the total categories of replies (see Table 5) also showed no significant difference in their performances ($\chi^2 = 6.0$, at $p = .05$ with 3 d.f. = 7.8). This may be disappointing to the teachers who had instructed on these topics during the intervening seventh grade; however, this lack of change in conceptual knowledge agrees with the findings of previous studies on misconceptions that show little change in beliefs after teacher-directed instruction (Driver & Easley, 1978). In comparing the overall performance to the previous study (Klein 1982), the students used 62.7% correct replies compared to 60.4% for the 6th graders in Minnesota and 29% for the 3rd graders. No statistical data was available for a more rigorous comparison. This close agreement also supports the adequacy of the paper-and-pencil approach for eliciting and assessing conceptions.

Table 5.

Distribution of Answers on the Earth, Sun, Moon Test.

n =	Grade	Blank	Correct	Incorrect	Indecipherable	Total
15	6th	49 (18%)	100 (37%)	101 (37%)	20 (8%)	270
8	8th	25 (17%)	69 (48%)	37 (26%)	13 (9%)	144

Study 2.

In the comparisons of the students' knowledge of the earth and sun relationships by the newly developed instrument, the test scores of the ability-grouped classes were significantly different from each other at both schools as shown by the t-tests and overall ANOVA ($t = 3.55$ and 2.36, $t_{.05} = 2.1$). The ANOVA also showed there to be significant differences on the performance of the students at the two schools on the pretest. In addition, an ANOVA run on the four classes at the inner-city school that were not purposefully grouped showed no significant differences between the classes' performance on the pretest, even though there were significant differences between the high and a low class when compared alone. For pretest and posttest average schores by class, see Table 6.

There were no significant differences between classes at the private school ($t = .67$) where no differences in the general ability of the classes was reported by the teacher. There was also no significant differences between paired pretests and posttests ($t = .45$)(these students served as a retest control group). Retest correlation was .83.

Table 6.

Pretest and Posttest Averages and Deviations by School and Class.

School	Class	(n=)	Pretests	Matched	Matched Postests	Posttests
Rural	Low	(26)	4.9 + 1.9	4.8 + 1.9	7.5 + 1.9 (n=22)	
	High	(24)	7.3 ± 3.0	7.0 ± 2.8	8.4 ± 2.5 (n=22)	
Private		(27)	8.2 ± 2.9	8.2 ± 3.0	8.5 ± 2.3 (n-24)	
		(21)	7.7 ± 2.5	(same)	7.7 ± 2.2 (same)	
Inner-	(High)	(23)	8.5 ± 2.0	8.5 ± 1.9	9.8 ± 1.9 (n=20)	9.4 ± 2.0
city,		(18)	5.7 ± 2.8			
GT		(19)	6.9 ± 3.0	6.7 ± 3.1	8.7 ± 2.4 (n=15)	8.3 ± 2.7
		(21)	5.0 ± 2.0			

Internal reliability on the pretests was .73. There were some problems with students understanding the wording of two items as reported by the teachers (a different item at each school). Although this wording could not be changed for the posttest, the second version of the instrument has been modified. Student replies were very similar on items that had been part of the first test. A breakdown of replies is included in Table 7.

Table 7.
Student replies on the Earth and Sun Test, version I.

Questions & Replies	Rural (50)	In-city (81)	Private (48)	Total (179)	Percent	(1st)
1. Earth's shape.						
a. Spherical	36	56	39	131	73%	(54%)
b. Round	7	16	5	28	16%	(29%)
c. Circle	6	8	4	18	10%	(17%)
2. Cause of day & night.						
a. Earth's rotation	22	43	27	92	51%	(46%)
b. Earth's revolution	12	22	15	49	27%	(8%)
c. The Sun moves.		3	1	4	2%	(8%)
d. Other	16	13	5	34	19%	(38%)
3. Other motion of Earth & Sun.						
a. Earth orbits Sun	10	34	18	62	35%	(25%)
b. Earth rotates	2	4	2	8	4%	
c. Other	8	9	10	27	15%	(42%)
4. Why Sun sets later on West Coast.						
a. Turns to Sun later	23	33	24	80	45%	
b. Diff. time zones	11	19	18	48	27%	
c. Sun is moving	3	4	3	10	6%	
5. When are days longest?						
a. Summer	33	57	36	126	70%	(63%)
b. Spring	11	10	4	25	14%	
c. Winter	1	4	7	12	7%	

Table 7, Student replies on the Earth and Sun Test. (continued)

Questions & Replies	Rural (50)	In-city (81)	Private (48)	Total (179)	Percent	(1st)
6. Why are days longer?						
a. Tilted toward Sun	4	12	9	25	14%	(4%)
b. Daylights savings	9	17	7	33	18%	(13%)
c. Sun out longer	7	14	4	25	14%	
d. Closer to Sun	5	9	6	20	12%	(17%)
e. We rotate slower	4	5	5	14	8%	
7. When are days shorter?						
a. Winter	36	63	41	140	78%	(71%)
b. Fall	9	7	1	17	9%	
c. Summer	1	4	6	11	6%	
8. Why are days shorter?						
a. Tilted away fm Sun	4	1	9	24	14%	0
b. Daylights savings	7	10	7	24	14%	(13%)
c. Sun not out much	5	3	5	13	7%	
d. Further fm Sun	5	12	4	21	12%	(17%)
e. Cloudy a lot	5	5	3	13	7%	
f. We rotate faster	4	4	4	12	6%	
9. When days and nights equal?						
a. Spring	26	48	34	108	63%	
b. Fall	28	42	32	102	60%	
c. Summer	15	11	3	29	17%	
d. Winter	8	11	4	23	13%	
10. Why are they equal?						
a. Axis not tilted	2	7	7	16	9%	
b. No time change	1	2	2	5	3%	
c. Sun is the same	4	2	2	8	5%	
d. Same dist. fm Sun	3	5	6	14	8%	
e. Beg. of seasons	3		3	6	4%	
f. We rotate the same	3	7	3	13	7%	
g. The Earth moves		11			6%	

On the posttests for the four groups being compared, there were significant gains as compared to the pretest scores in all classes using matched t-tests. An ANOVA conducted on the four classes posttests showed there to still be significant differences in the average scores between the ability groups, but not between schools. When the posttest scores were corrected for pretest scores in an Analysis of Covariance, there proved to be no significant differences between the posttest scores of the ability groups or the schools. This indicates the score on the pretest was the greatest predictor of score on the posttest. Looking at the gains scores, it was seen that the students who scored lowest on the pretest tended to have the highest gains while those who scored highest tended to have the lowest gains. This would match what would be expected in a sigma learning curve.

An item-by-item analysis (see Table 8) also showed individual differences between what was learned by the students in the four classes. Based on the retest control group posttests that showed an average gain of .2 possibly due to test learning, an average gain of 20% of the students in the class was chosen as an indicator of significant gain on an item.

Overall, the items that were around average difficulty (.3 to .7) and discriminated well tended to show significant increases in the number of students who answered them correctly between the pre- and posttest. These items tended to be informational items such as when the periods of daylight were longer and shorter. For the most part, the didactic instruction with cooperative review in the rural school proved superior in helping the students learn these types of informational concepts (as shown by the posttest) as compared to the activity-oriented instruction .

The other category of items that showed significant increases between the pre- and posttests were those items on the pretest that were both poor discriminators and difficult (Difficulty Index < .5). These appeared to be mostly conceptual items that the students as a group did not know prior to instruction.

In only one major instance did the activity-oriented curriculum prove superior to the didactic instruction as shown by posttest gains. That was in the questions dealing with the difficult concept

Table 8.
Item analysis showing proportion correct for matched students.

Item	Control pre	Control post	In-city pre	In-city post	Rural pre	Rural post
n =	(24)	(21)	(20)	(15)	(22)	(22)
M =	8.1	8.5	7.7	7.7	8.6	8.9	7.5	8.8	7.0	8.4	4.7	7.1
1	.79	.88	.86	.95	1.0	1.0	.67	.67	**.82**	**.50**	**.59**	**.72**
	m = **.87 ±.06**								-7 stu's		+3 stu's	
2	.71	.67	1.0	.86	.65	.70	.47	.57	**.59**	**.77**	**.32**	**.68**
	m = **.80 ±.14**								+4 stu's		+8 stu's	
3	.92	.96	.95	.95	.90	.75	1.0	1.0	.91	1.0	.82	.91
	m = **.95 ±.02**											
4	**.54**	**.75**	.57	.52	.70	.55	**.47**	**.73**	.45	.54	**.36**	**.59**
	+5 stu's		**.6 ±.09**				+4 stu's					+5 stu's
5	.46	.54	.38	.24	.40	.25	.33	.27	**.23**	**.59**	**.14**	**.50**
	m = **.52 ±.04**								+8 stu's		+8 stu's	
6	**.33**	**.63**	.33	.48	**.70**	**.45**	.60	.60	**.36**	**.68**	**.05**	**.32**
	+7 stu's		**.44±.12**		-5 stu's				+7 stu's		+6 stu's	
7	.50	.42	.48	.57	.60	.50	.40	.33	**.41**	**.27**	.50	.45
	m = **.49 ±.05**								-3 stu's			
8	.79	.83	.67	.86	.95	.95	.80	.93	.86	.86	**.45**	**.82**
	m = **.79 ±.07**										+8 stu's	
9	.29	.25	.1	.1	**.20**	**.40**	**.33**	**.51**	.14	.18	0.0	.05
	m = **.19 ±.09**				+4 stu's		+4 stu's					
10	.92	.92	.76	.90	.95	.95	.87	1.0	.77	.91	**.64**	**.86**
	m = **.88 ±.07**										+5 stu's	
11	.29	.25	.10	.05	**.05**	**.40**	.33	.40	.14	.14	0	0
	m = **.17 ±.10**				+7 stu's							
12	.67	.63	.71	.57	.75	.75	**.40**	**.60**	**.59**	**.82**	**.36**	**.55**
	m = **.65 ±.05**						+3 stu's		+5 stu's		+4 stu's	
13	.63	.63	.67	.57	.70	.80	.60	.67	.68	.77	.45	.50
	m = **.63 ±.04**											
14	.21	.25	.10	.05	**.05**	**.45**	.20	.27	**.05**	**.36**	0.0	0.0
	m = **.15 ±.08**				+8 stu's				+7 stu's			

of the Earth's tilt causing differing lengths of the lighted and night portions of a day. Thus it would appear that an activity-oriented approach helps students develop more difficult concepts correctly.

CONCLUSIONS

It would appear that the open-ended question, paper-and-pencil instrument is adequate for eliciting student conceptions in this area of science. By inspection, the student answers were unique and varied. The students also tended to use the same ideas for questions dealing with different aspects of the same concept. By analysis, the instrument was reliable and reflected general differences in ability. In addition, it appears to be able to discriminate between different types of instruction on an item-by-item basis.

The next step will be to use this instrument in conjunction with a concept elicitation experiment where the teachers will use the student answers on it to help them assess the preconceptions held by their students. This will also give data on iterrater reliability using the method of coding developed for such open replies. Different approaches to dealing with the misconceptions will be used in the activity-oriented curriculum including teacher-led discussions of preconceptions and such discussions being conducted in cooperative learning groups.

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APPENDIX

Copies of the instruments:

1. Samples of the Earth-orientation task versions.

2. The Earth, Sun & Moon questions.

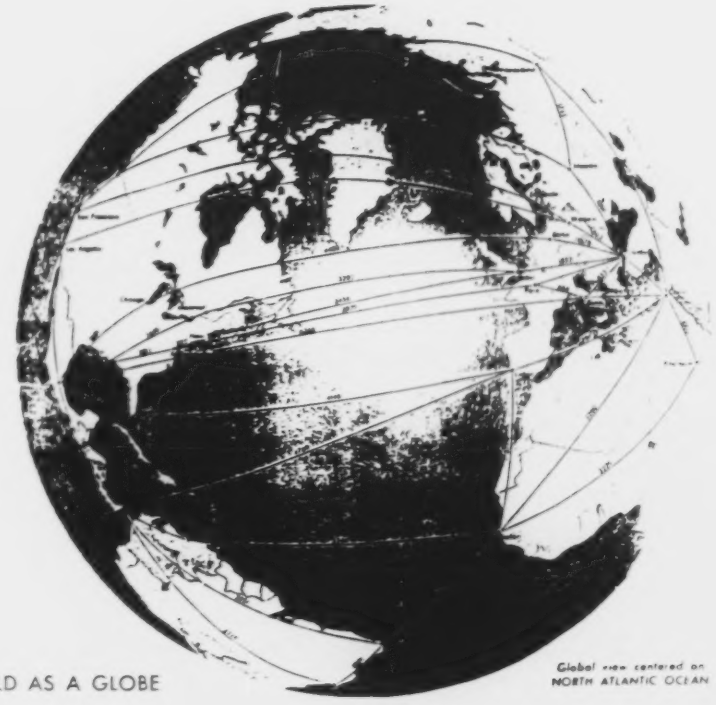
3. The Earth and Sun Instrument, version 1.

4. The Earth and Sun Instrument, current version.

5. Coding Sheet for the Earth and Sun Test

STANDING ON THE EARTH. As you may know, a globe is sometimes used to represent the earth.

How would you represent a person standing on the earth using this globe? Now draw it.



Global view centered on NORTH ATLANTIC OCEAN

THE WORLD AS A GLOBE

DROPPING A ROCK. <u>For a person standing on the earth</u>,

1. If a person dropped a rock, how would it fall?

Draw it on the globe.

THE WORLD AS A GLOBE

THROWING A ROCK UP. For a person in North Carolina.

1. If the person threw a rock up, how would it travel?

2. Would the rock just keep going in this direction?

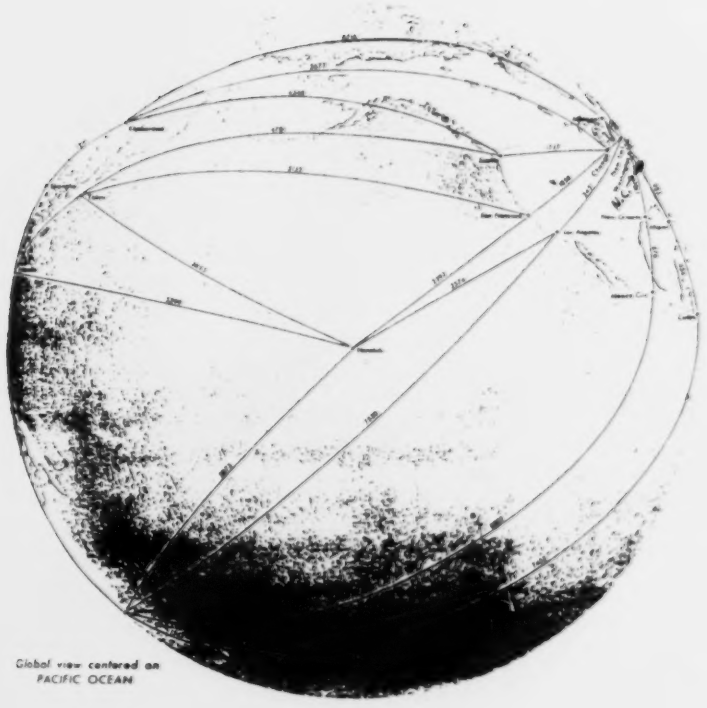
(if 'YES' go to question 5.)

(if 'NO' continue with question 3.)

3. What would happen to the rock after it has gone up for a little while?

4. Why does the rock do this?

5. Draw the complete path of the thrown rock on the globe after it is thrown up and until it stops.



Global view centered on PACIFIC OCEAN

A SHAFT COMPLETELY THROUGH THE EARTH. <u>For a person standing in Australia</u>.

1. If the person were to dig a shaft completely through the earth so that a rock dropped into it would come out the other end, how would the shaft have to be dug through the earth? Draw it on the globe.

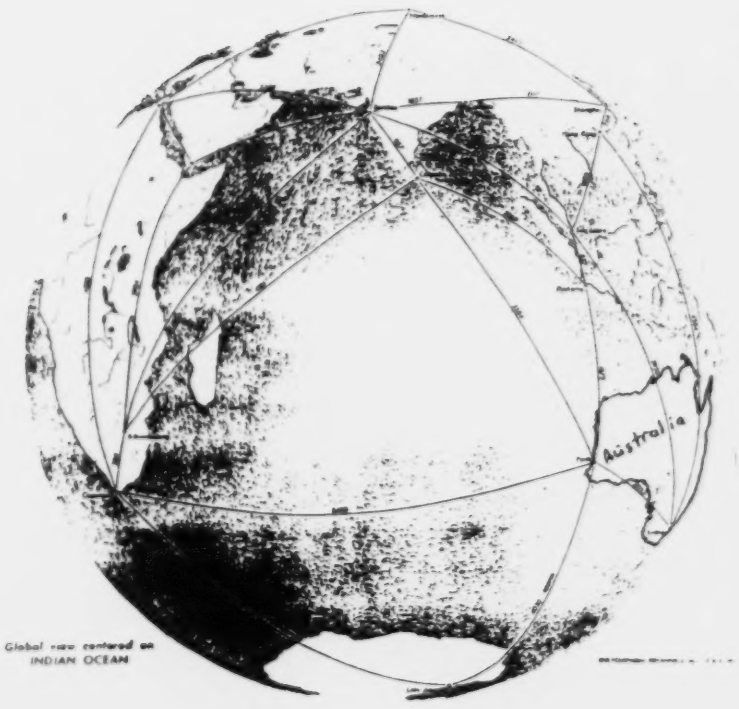
2. Would the speed of the rock falling through this shaft change at any time?

(if 'YES', When and how would it change?)

3. What would the speed of the rock be like when it came out the other end of the shaft?

4. What would the rock do after it has come out the other end of the shaft?

5. Draw the path of the rock falling through the shaft and how it would travel after it exits the shaft.



SHAPE OF THE EARTH.

1. How would you describe the shape of the earth?

2. Draw the general shape of the earth as you believe it looks.

THE MOON.

1. Where is the moon in relation to the earth?

2. Draw the moon below as it would appear relative to the earth.

3. Why can't we see the moon all the time in the sky?

4. If you think the moon or the earth are moving, how is it moving?

THE SUN

1. Where is the sun in relation to the earth?

2. Why can't we see the sun at night?

3. Which is moving, the earth or the sun?

How is it moving?

4. Draw the size of the sun compared to the size of the earth.

DAYLIGHT

1. Have you ever noticed that the periods of daylight are longer or shorter during certain times of the year?

(If 'YES', answer #2 and 3 before going to next page.)

2. During what time of the year is there more daylight?

Why is there more daylight during this part of the year?

3. During what time of the year is there less daylight?

Why is there less daylight during this part of the year?

4. If you can, draw a picture showing why there is more daylight during certain times of the year and less daylight during other times of the year.

THE EARTH, MOON AND SUN

1. Which is closer to us, the moon or the sun?

2. Which is biggest, the earth, moon or sun?

3. Which is smallest, the earth, moon or sun?

4. Draw the relative sizes of the earth, moon and sun below.

CHANGES IN THE MOON

1. Draw as many different shapes as you can think of that you have noticed the moon to have on different nights.

2. Why do you think the moon has these different shapes at different times?

3. If you can, draw a picture that shows why you think the moon has a different shape at different times.

Version 1.

Name: _____, Class Period: _____, Date: _____

Teacher: _____, School: _____

Answer the following questions as best you can. Answer each one with a full sentence. For example: **Where is the sun in relation to the Earth?** The Sun is far away from the Earth in outer space.

1. Describe the shape of the Earth, give an example to make your answer clear.

_____

_____

2. How can people tell that the Earth is this shape? _____

_____

_____

3. During a clear day, you can see the sun rise, move across the sky and set. Which is really moving, the Earth or the Sun? (circle your answer)

4. Describe this motion as best you can. _____

_____

_____

5. Where does the Sun go at night? _____

_____

_____

6. This is not the only way the Earth and Sun move with respect to each other. If you know the other type of motion, describe it. _____

_____

_____

7. Most people who have watched football games broadcast from the West Coast know that there is still daylight there for about 3 hours after the Sun has already set here in North Carolina. How can that be? _____

_____

_____

_____

8. Most people have noticed that there are some times during the year when we have more hours of daylight and other times when we have fewer hours of daylight.

a. During what season do we have the most hours of daylight? _____

b. Why is there more daylight during this part of the year? _____

_____

_____

_____

c. During what season do we have the least hours of daylight? _____

d. Why is there less daylight during this part of the year? _____

_____

_____

_____

9. There are also two times of the year when there is almost exactly the same number of hours of daylight and darkness in a day. When are these two times?

a. _____

b. _____

10. What causes the hours of light and darkness to be even at these times of the year?

_____

_____

_____

BONUS! If you can, draw pictures showing why there are more hours of daylight or less hours of daylight or the same number of hours of daylight at certain times of the year.

Name: _____ Class Period: _____ Date: _____
Teacher: _____ School: _____

EARTH AND SUN TEST

Answer the following questions as best you can. Answer each one with a full sentence. **For example:** Where is the Sun in relation to the Earth?
The Sun is far away from the Earth in outer space.

1. Describe the shape of the Earth. Use an example to make your answer clear.

_____
_____

2. What is the shape of the Sun? Also use an example of something else that is the same shape to make your answer clear.

_____
_____

3. During the day, the Sun can be seen to rise, move across the sky, and set. What is causing this movement that we see?

_____
_____
_____

4. What happens so that we are not able to see the Sun at night?

_____
_____
_____

5. Most people who live on the East Coast have watched football or baseball games broadcast from California. If you have done so, then you may have noticed that there is still daylight on the West Coast for about three hours after the Sun has already set here in North Carolina. How can that be?

_____
_____
_____

6. Your answer to question number 3 is not the only way the Earth and Sun move with respect to each other. If you know the other way, describe it.

_____
_____
_____

Most people have noticed that there are some times during the year when we have more hours of daylight and other times when we have fewer hours of daylight.

7. During what season do we have the most hours of daylight? _____

b. Why is there more daylight during this part of the year?

_____
_____
_____

8. During what season do we have the least hours of daylight? _____

d. Why is there less daylight during this part of the year?

_____
_____
_____

9. There are also two times of the year when there is almost exactly the same number of hours of daylight and darkness in the day. When are these two times?

a. _____ b. _____

10. What causes the hours of daylight and darkness to be about even at these two times of the year?

_____
_____
_____

Coding for Answers to Earth and Sun Test

1- 1. **The Earth is spherical (a sphere) or round like a ball.**
2. The Earth is **round** (no clarifying example).
3. _____

6. The Earth is a **circle** (no clarifying example).
7. _____

2- 1. **The Sun is spherical (a sphere)** or **round like a ball.**
2. The Sun is **round** (no clarifying example).
3. _____

6. The Sun is a **circle** (no clarifying example).
7. _____

3- 1. **It is caused by the Earth spinning/rotating (on its axis).**
2. The Earth revolves every 24 hours/in an East to West motion.
3. The Earth moves in a circle/circular motion.
4. The Earth is moving slowly.
5. The **Sun rises and sets**/moves across the sky.
6. The Earth revolves/rotates around the Sun.
7. The Earth tilts/is tilted.
8. The Sun revolves around the Earth.
9. _____
10. _____

4- 1. **The Earth turns/rotates away from the Sun.**
2. The Sun goes to the West/sets.
3. The Sun is still in the sky/atmosphere (somewhere), we can't see it.
4. _____
5. _____
6. The Sun goes to the other side of the Earth.
7. The Earth goes around (to the other side of) the Sun.
8. The Sun goes behind clouds/the Moon.
9. The Sun goes to the Southern Hemisphere/below the Equator.
10. _____

5- 1. **The West Coast has not turned/rotated toward the Sun yet.**
2. They are in a different time zone/different place.
3. They are closer to where the Sun sets.
4. They are receiving the late rays of the Sun
5. _____
6. The Sun is moving.
7. Because of the Earth's tilt.
8. The Sun is so bit it can still shine there.
8. The Sun revolves around the Earth.
9. _____
10. _____

6- 1. **The Earth orbits/revolves around the Sun.**
2. The Earth **rotates** around the Sun.
3. _____
4. _____
5. _____
6. The Earth spins/rotates.
7. The Earth tilts.
8. _____
9. _____
10. _____

7- 1. **Summer**
2. Spring
3. (Spring or Summer months).
6. Autumn/Fall
7. Winter
8. (Fall or Winter months).

b- 1. **The (part of the) Earth (where we live) is tilted toward the Sun.**
2. The Earth is turned a certain way/the tilt is changed.
3. The day is longer than the night/the Sun is out longer.
4. Because it is spring/summer, it is hotter.
5. _____
6. It is due to daylight savings time.
7. The Earth is closer to the Sun
8. The Earth's rotation/revolution is slowed.
9. It is less cloudy (so the Sun is out more).
10. _____

8- 1. **Winter.**
2. Autumn/Fall.
3. (Fall or Winter months).
6. Spring.
7. Summer.
8. (Spring or Summer months).

d- 1. **The (part of the) Earth (where we live) is tilted away from the Sun.**
2. The Earth is turned a certain way in relation to the Sun.
3. The day is shorter than the night/the Sun is not out as long.
4. It is wintertime/colder.
5. _____
6. It is due to daylight savings time.
7. The Earth is further from the Sun.
8. The Earth rotates/revolves faster.
9. It is cloudy a lot / the Sun is hidden more.
10. _____

9a & b 1. **Spring and Fall/Autumn (equinoxes).**
2. Summer and Winter (if one is substituted for Spring or Fall).
3. (Summer/Spring or Fall/Winter months).
6. Winter and Summer (if one is substituted for Spring or Fall).
7. (If the wrong months are given for the second answer).

10- 1. **The Earth is neither tilted toward nor away from the Sun.**
2. The Earth/World is even.
3. It is the beginning of the seasons/when we change from long to short days (vice-versa).
4. The temperature/weather/light are the same.
5. It is because of the Earth's movement/rotation around the Sun.
6. The time change is the same.
7. The Earth is the same distance from the Sun/(it's where we are in relation to the Sun).
8. The Earth rotates/revolves at the same speed.
8. The Sun revolves around the Earth.
9. _____
10. _____

? - for answers that are not understandable, 0 - for no answer.